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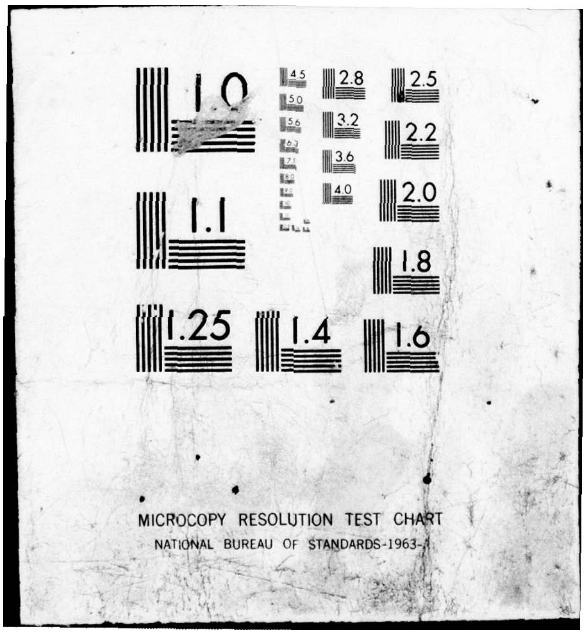
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After more than 6 months of practice on the memory span task, a single subject was able to increase his digit span from 7 digits to about 40 digits. This memory feat is accomplished with the development of a mnemonic system and a control structure for retaining the order of items. There is no evidence of an increase in short-term memory capacity.

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William G. Chase and
K. Anders Ericsson
Carnegie-Mellon University

Paper presented at the Nineteenth Annual Meeting of the Psychonimic Society, San Antonio, Texas. November 9-11, 1978.

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Today, we want to describe a subject (SF) we have been running on the memory span task for 6 months, and in that time, his performance has improved from 7 digits to about 40 digits. How does he do it?

Our research into this question has proceeded in three stages. First, we use retrospective verbal protocols to figure out what SF is doing, at least at the levels available to conscious memory. Second, we think we understand SF's memory behavior in terms of current memory theory, and we think we can generate a model of his performance and instantiate it in a computer simulation. Finally, we test the theory by conducting experiments on SF.

Method

Our current procedure is to run SF ten trials a day, although in the beginning, when SF's span was small, we ran as many as 55 trials a day. To begin a trial, SF is first told how many digits he will hear, and then he describes to the experimenter how he plans to group the digits. When he is ready, the digits are read by the experimenter at a rate of 1 digit/sec. SF then recalls the digits, taking as much time as he needs. If he recalls all the digits in their correct order, the number of digits is increased by 1 digit for the next trial. Otherwise he gets 1 less digit for the next trial. We try to start SF below his current span by beginning with a sequence that is two digits less than his previous weekly average. After SF has finished his recall, we collect retrospective reports randomly on half the trials. He never knows ahead of time when a retrospective report will be required. Finally, after each daily session, we ask SF to recall as many groups (3- and 4-digit sequences) as he can from that day.

Our procedure has changed quite a bit over the six months since we started. Since we were interested in the effects of verbal reports on the

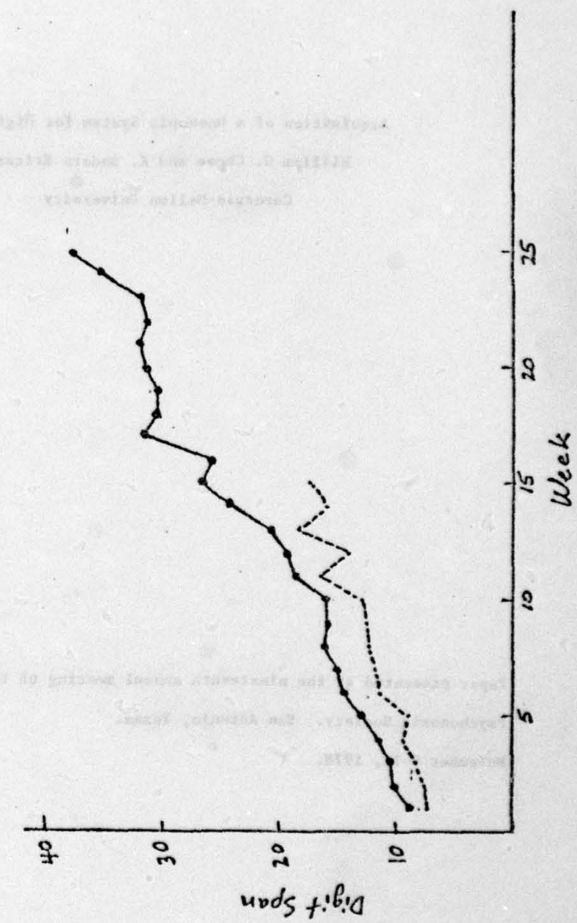
memory span task, we initially used a variety of conditions involving immediate vs. delayed (20 sec.) recall, with or without a retrospective report at the end of the trial. Also, the 20 sec. delays could either require a talking-aloud protocol or silence. These various conditions were eventually dropped when it became apparent that they made little or no difference. We also used a warm-up procedure in which SF started with 5 digits and continued with an ascending sequence until he made an error. This procedure eventually became too time-consuming as SF's span increased, and we consequently dropped it also.

Over the course of six months, we have run SF in over a hundred daily sessions of 1-2 hours in duration, totalling approximately 150 hours of practice in the laboratory. We generally run five sessions per week, but occasionally we ran less. After the first two months, as our theoretical ideas began to take shape, we started conducting experiments on SF. (Our first experiment was Session #42.) We first started running one experimental session and four regular sessions in a week, and later we ran two experimental sessions and three regular sessions. During the last month and a half, we were able to run only four sessions per week, two regular and two experimental. Up to th's point (Nov. 13, 1978), we have run approximately 115 one-hour sessions, including 23 experimental sessions.

In what follows, we will first describe SF's memory span performance and our analysis of it, and then we will present some of the experiments we have conducted on SF.

The Learning Curve

The first slide shows SF's digit span as a function of the amount of practice. Starting with a span of about 7 digits, SF shows roughly a linear



increase of about 1.2 digits per week in his span. The dashed line shows comparable performance on the initial ascending warm-up trials, until we dropped this procedure after about 15 weeks.

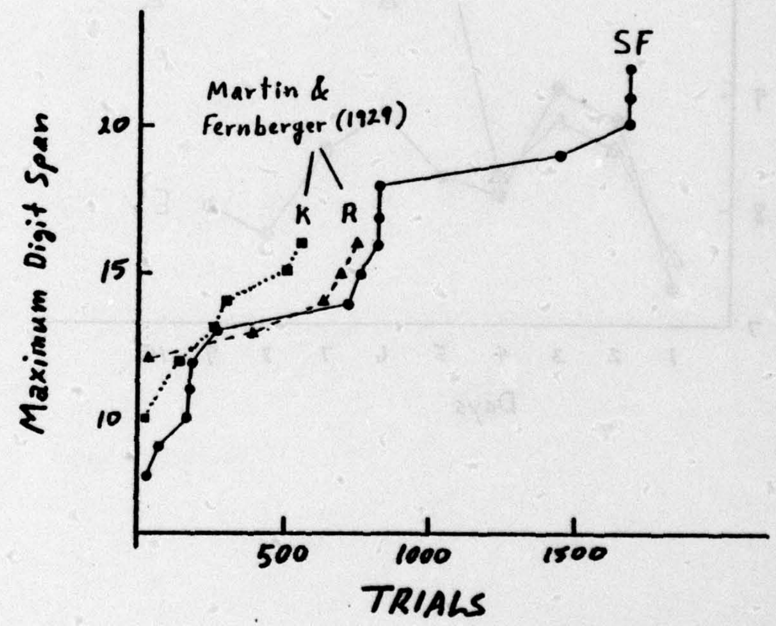
The next slide compares SF with two subjects from an early study by Martin and Fernberger (1929). This slide shows the maximum digit span as a function of the number of trials it took to get there. In this study, Martin and Fernberger practiced two highly motivated students for about two months, and the practice effects are very similar for all three subjects. This slide shows the maximum digit span of SF as of last summer (Session #39). His maximum digit span is now 41 (Session #115: Nov. 13, 1978).

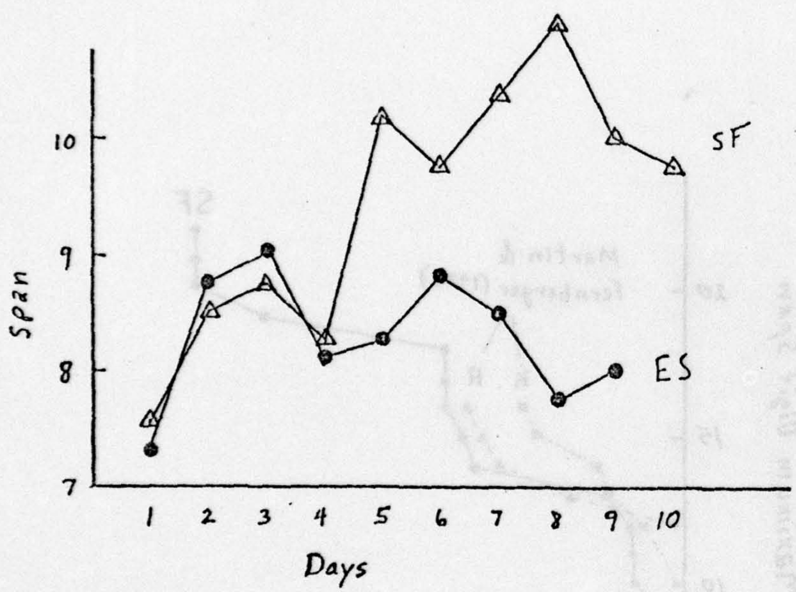
The next slide compares SF's performance with an unmotivated subject who eventually became disgusted and quit after about two weeks. In contrast to SF, this subject never developed a mnemonic and consequently was never able to improve very much. Notice that the performance of both subjects is very comparable through the first four days of the experiment. In fact, on Day 4 SF gave us a fairly lengthy verbal report about how he had reached his limit and no further improvement was possible.

And then, on Day 5, something very interesting happened. There was a large improvement in SF's digit span (a jump of 4 standard deviations from the day before), and, for the first time, SF began to report the use of a mnemonic aid. From this point on, SF showed a steady increase in his digit span as he developed his mnemonic system and the accompanying control structure. It is our analysis of this mnemonic system and its control structure that we want to report today.

The Mnemonic System

The next slide shows a detailed protocol of a trial on which SF achieved a new high of 22 digits. On this trial, the experimenter read the





Protocol of SF reaching a new high of 22 digits
Session #39
July 11, 1978

[Digits Presented 1 per sec.] (4 1 3 1 7 7 8 4 0 6 0 3 4 9 4 8 7 0 9 4 6 2)

[20 second delay] ["nine-four-six-two" rehearsed about 15 times rapidly in a whisper]

[Signal to recall] Time (sec)

0 All right. All right. All right. All right. All right. All right. All Right.
5 Oh geez!
Ok. Ok. Ok.
10 All right now...now this one is ...un it it...uh...oh.
15 ok.ok.ok.ok.
20 Oh!
Four thirteen point one
25 Seventy-seven eighty-four
30 Oh six oh three
Four nine four, eight seven oh,
35 Nine forty-six
Oh no!
40 Nine forty-six point...
Oh!
45 Nine forty-six point...
two!
50 (Can I please have it again once more please?)
Oh no. Oh no. Oh no. Oh no.
55 What?
(Can you take it once more, please?)
60 Oh....Oh.
All right. All right. All right.
1:05 It's four thirteen point one mile.
Then seventy-seven eighty-four.
1:10 Then oh six oh three.
Then four nine four.
Eight seven oh.
1:15 Nine...forty-six.
What'd you run it?
1:20 I ran it in nine forty-six point...two!
1:25
(Thank you. Please tell me everything you can remember.)
All right. All right. All right. All right. All right.
1:30 Starting from the beginning.
I made the four thirteen point one a mile time.
I just remembered the seventy-seven eighty-four.

1:35 Ok? Ok? Right. Seventy-seven eighty-four.
1:40 Then...then...then I...
(Any pattern?)
What?
(Any pattern?)
No. No. Nothing. Just like seventy-seven eighty-four.
1:45 Ok. Then I made the oh six oh three, I made that a mile time.
1:50 Then I remembered the four nine four
and the eight seven oh.
I just had to remember those.
Then, I remembered the nine forty-six point...two!
1:55 It's definitely point two, two-mile.
2:00 I said, so I said to myself "What did you run it in?"
I ran it in nine forty-six point two. Nine forty-six point two. Right.
2:05
2:10 (Uh...Could you uh...tell me about the last three groups of digits. I'm, I'm not sure that I...)
Um. It was, it was four nine four. Nothing. Eight seven oh. Nothing.
2:15 Then nine forty-six point two two-mile.
2:20
(Did you rehearse anything?)
Yes. Nine forty-six point two
keeping in mind the first two sets of three.
2:25
(Uh. Were you unsure of any of the digits?)
2:30
(Sigh) No...No. No.
2:35

digits at the rate of 1 digit per sec., and then there was a 20-sec. delay followed by recall, and then the experimenter requested a retrospective report.

The most interesting thing to notice about the protocol is the mnemonic: SF is coding the digits as running times. It turns out that SF is a very good long-distance runner,[1] and he uses his knowledge of various times for events as a mnemonic aid.

The next slide shows a protocol analysis of the five trials on July 11 leading up to and including the new high of 22 digits. (The previous high was 19 digits, obtained seven days earlier.) For each trial we have coded the grouping structure (on the left), the actual digits recalled, and the mnemonic reported in the verbal report (on the right). The digits that SF reported rehearsing are bracketed in the protocol. A bar is drawn over pairs of digits that were recalled as a 2-digit number, such as fifty-six $\longrightarrow \overline{56}$. This slide illustrates the preponderance of running times. Another thing to notice is the systematic grouping structure, which we will go into later.

The next slide illustrates the scope of the running-time mnemonic. After each session, SF is asked to recall as many groups of digits as he can, and this slide is a transcription of the recall on July 11. (The groups of digits in parentheses are the ones that could not be found in the protocols.) First, notice that SF has 10 different categories of running times, ranging from 1/2-mile times to 10-mile times, and from his protocols we know that he has many sub-categories within these. Typical instances of mile times might be "near-world-record mile time," "very poor mile time," "average mile-time for the marathon," etc. Another thing to notice is the very systematic nature of SF's recall (left-to-right and top-to-bottom in the slide). He begins with the smallest times and

Protocol Analysis July 11

18

4	56:44	10 miles
4	66:10	10 miles
4	6:41.0	1 mile
3	[876]	Pattern
3	[066]	Repeat

19

4	0516	1 mile
4	7274	Pattern
3	389	--
3	343	--
5	[204.77]	1/2 mile

20

4	7271	Pattern
4	19:66	5 miles (Wierd)
3	696	—
3	605	—
6	[989606]	-- 1 mile

21

4	7264	Pattern
4	7484	Pattern
4	2460	5 miles (converted)
3	165	--
6	[988860]	--

22

4	413.1	1 mile
4	7784	--
4	0603	1 mile
3	494	--
3	870	--
4	[946.2]	2 miles

After-Session Recall July 11

1/2 mile	233.6	(257)								
3/4 mile	(312)									
1 mile	343	354	413.1	418	432.1	507	(516)	529	601	641
2 miles	723	826	820	946.2	935					
3 miles	--									
4 miles	2252									
5 miles	2966									
10 kmt	3215									
15 kmt	—									
10 miles	5614	5649	6610							
Other	000	494	870	(057)	7784					

systematically works his way up, category by category, with very few reversals. On very rare occasions, a running time triggers episodic recall of other times from the same trial. Most of the time, however, SF simply uses the number line as a ready-made retrieval device to scan his semantic memory for running times. This strategy also proves useful in the memory span task because when SF gets stuck in recall, he very often falls back on this time-consuming scan of semantic memory.

Finally, notice that a few non-times are also recalled at the end. Over the last three months since July, however, SF has developed additional mnemonics to supplement his running times. These additional mnemonics are ages and dates, which SF uses when a running time can't be used. For example, 496 can't be a time because the second digit is too big, and under these circumstances SF codes this as 49.6 years old.

A statistical analysis of SF's protocols reveals that about 65% of his groups are coded as running times, and this percentage has remained fairly stable over the past several months. What has changed however, is the percentage of uncoded groups, which has dropped from about 30% to 5% over the past three months, and this drop is accompanied by a corresponding increase from 0 to about 25% incidence of ages as mnemonic.

An analysis of the after-session reports reveals that SF remembers a remarkable amount of material from the session. On average, he is able to recall 65% of the groups from the session, and this percentage varies a little bit as a function of various conditions. For example, he is able to recall about 10% more from the second half of the session than the first half of the session, he is able to recall about 20% more from those trials on which he gave a retrospective verbal report, and there are also some

slight variations in serial position. We have conducted a couple of experiments to further quantify this effect. In one experiment, we gave SF all but the last digit from 100 groups he had seen that day, and we asked him to supply the last digit. SF was able to recall the last digit 67% of the time. In another experiment, we asked SF to recognize groups from an entire week (4 days) in an old-new recognition paradigm. Under these circumstances, SF's recognition was perfect for the same day, virtually perfect for the previous day (only one false alarm), and he still showed substantial recognition for the first two days of the week. For the first two days of the week, the hit rates were .65 and .81 respectively, and the false alarm rates were .4 and .1, respectively. These convert to d's of .64 and 2.16, respectively.

In sum, these data illustrate that SF has very substantial recall and virtually perfect recognition of digit groups after an hour's practice. In comparison, unpracticed subjects in this task can remember virtually nothing from a session. The implication is that SF's mnemonic system in semantic or long-term memory underlies this long-term retention.

The next slide illustrates our analysis of SF's coding structure. SF codes digits into groups of 3 or 4 digits, and we have characterized each of these codes. In addition, on the right we have listed the date and session number when the various codes were first reported by SF. The significant part of this coding scheme is the invention of the time mnemonic on Day 5, and its extension to the 4-digit running times on Day 20 and decimal times on Day 26. Extensions of this basic code didn't occur until much later with the addition on Day 60 of a time with a preceding digit. SF uses this rule when the first two digits won't make a running time (e.g.,

Coding Structures

	Date	Session Number
XXX		
Time	May 19	5
Age + Decimal	Aug. 24	70
XXXX		
Time (3, 4, 5 10 MT)	June 12-13	20-21
Time + Decimal	June 20	26
X + Time	Aug. 9	60
Year	Aug. 15	64
Age + Age	Aug. 15	64

4822 = 4 + 2-mile time). Further additions occurred later when SF supplemented his running times with ages and dates. We have simulated a simple set of rules for this coding scheme which accounts for about 90% of SF's codes in his verbal reports.

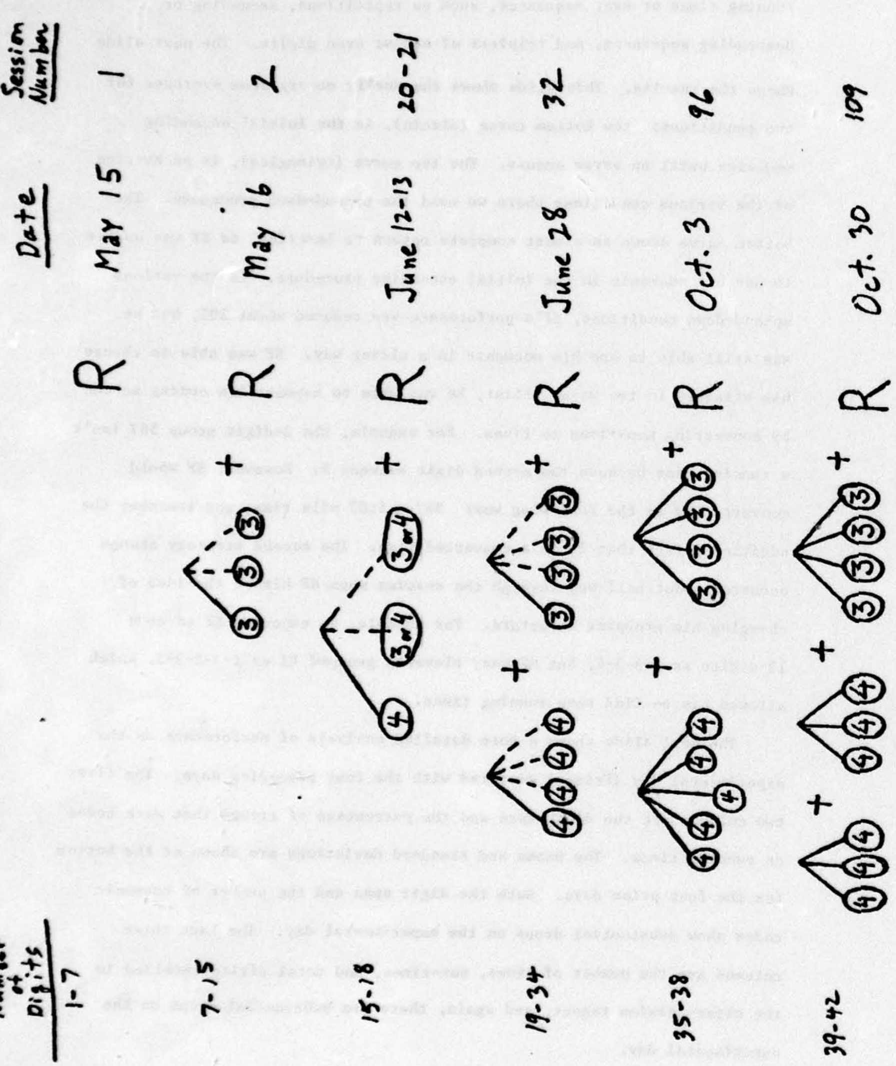
The Control Structure

The next question one might well ask is the following. If SF originally had a digit span of 7 digits, and he then learns to recode digits into 4-digit groups, how is it possible for SF to remember more than 7 groups of digits? How can SF's memory span exceed a maximum of 28 digits according to his scheme? The answer to this question comes from an analysis of SF's control structure.

By control structure we mean the memory structures and processes that are used to organize the sequencing of digits, rehearse, keep the order straight, and produce a correct recall. Control processes in general are procedures that subjects can use or not, as they wish, depending on their strategy. That is, control processes are not obligatory and automatic; the subject has control over them, and usually the subject can report them.

For our purposes, the two most important of these control processes in the digit-span task are rehearsal and grouping strategies. In the next slide, we have characterized these control processes, and the important changes that took place as SF's digit span improved, as revealed in the retrospective reports. On Day 1, SF simply attempted to hold everything in a rehearsal buffer (R). Rehearsal of the entire memory set is typical of subjects' initial behavior in a memory span task. The next day, SF began to code an initial group of 3 digits and then hold the remainder in a rehearsal buffer. At this point, as the number of digits increased, SF

Control Structures



systematically increased the rehearsal buffer from 4 to 6. With further increases in the number of digits, SF would not let the rehearsal buffer exceed 6. Instead he would cut the buffer back to 4 and add an additional group of 3 digits. The next advancement came as SF learned to generate 4-digit groups (Days 20-21). Probably the most important change came on Day 32, when SF began to organize his groups into hierarchical groups, which, for want of a better name, we will call super groups. (Besides the verbal reports, we have a large variety of converging evidence for the existence of these super groups, but we don't have the time to discuss them here.) This advancement is so important because it allows SF's digit span to exceed 7 groups. The next two advancements are interesting because they seem related to a fundamental capacity problem. SF experienced prolonged difficulty in expanding his super groups beyond 4 groups until he hit on the strategy of tagging the middle item in a super group with 5 groups (Day 96). He called it a "hitching post" or "peg." This allowed him to relate the two preceding groups and the two following groups separately to the middle item. He later broke up this super group into two new super groups, each containing three 4-digit groups. We believe that this advancement caused SF to move off a plateau in the learning curve that he had been on for about 7 weeks.

We think that this limit on super group size is consistent with Broadbent's (1973) analysis of short-term memory (STM) size. Broadbent claims essentially that long-term memory (LTM) is organized in clusters of 3 and 4 items because that is all the capacity that STM has to juxtapose items in order to form a hierarchical group.

This, then, is what we mean by the control structure. Over the course

of long hours of practice, SF has built up a set of grouping structures in long-term memory to which he can attach a semantic association. During recall, SF can systematically activate each successive node in these control structures, and the semantic association produces a corresponding activation in semantic memory of the to-be-remembered item. This is quite analogous to the Method of Loci. In other words, although we don't understand how this associative mechanism works, we believe it is the same mechanism that is used in the Method of Loci, the peg word method, and other mnemonic techniques based on meaningful associations. It seems apparent that some such control structure is necessary to keep the order of items straight, and to facilitate retrieval.

The Experiments

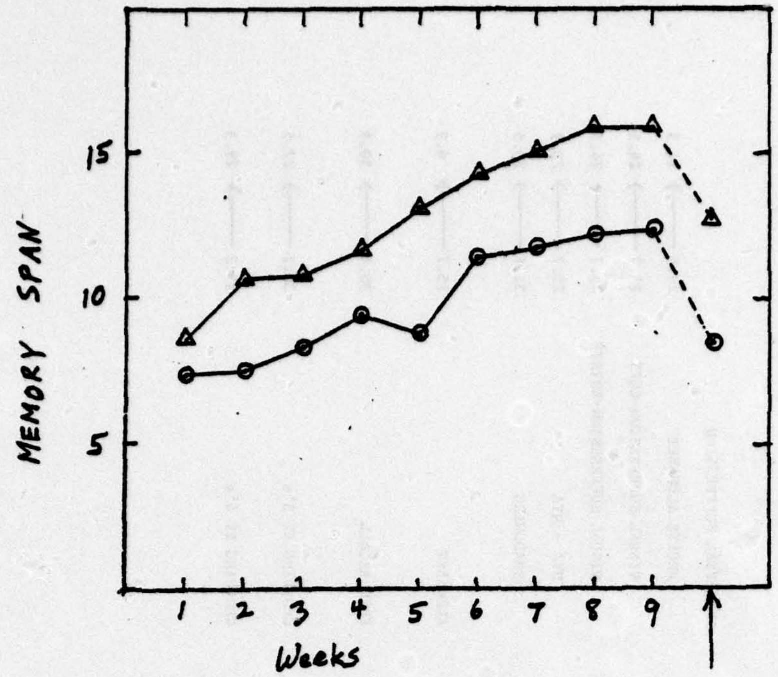
Up to this point, our analysis reveals that the two most important components of SF's digit-span skill are the mnemonic system and its control structure. Since our analysis is based mainly on SF's verbal reports, with no direct experimental control, the evidence can be characterized as a relatively weak descriptive analysis. What we need now is some stronger, more direct evidence, and this is what we report now.

Over the course of the past few months we have conducted over 20 experiments on SF. Our first experiment was run on Day 42, and we have conducted an experiment about once a week thereafter. Today, we will report on our first experiment in some detail, and then we will mention a few of the others in passing to give you an idea of the variety of things we are investigating.

Our first two experiments were designed to test our hypothesis that SF's running-time mnemonic was a critical component. In our first experiment we constructed the digit sequences so that SF's groups couldn't be

running times or easy sequences, such as repetitions, ascending or descending sequences, and triplets of odd or even digits. The next slide shows the results. This slide shows the weekly memory span averages for two conditions: the bottom curve (circle), is the initial ascending sequence until an error occurs. The top curve (triangles), is an average of the various conditions where we used the up-and-down procedure. The bottom curve shows an almost complete return to baseline, as SF was unable to use his mnemonic in the initial ascending procedure. In the various up-and-down conditions, SF's performance was reduced about 20%, but he was still able to use his mnemonic in a clever way. SF was able to change his strategy in two ways. First, he was able to augment his coding scheme by converting non-times to times. For example, the 3-digit group 567 isn't a running time because the second digit exceeds 5. However, SF would convert this in the following way: 567→6:07 mile time, and remember the additional fact that it is a converted time. The second strategy change occurred about half way through the session when SF hit on the idea of changing his grouping structure. For example, we expected SF to code 13 digits as 3-3-3-4, but SF very cleverly grouped 13 as 1-3-3-3-3, which allowed him to find some running times.

The next slide shows a more detailed analysis of performance on the experimental day (Friday) compared with the four preceding days. The first two columns are the digit span and the percentage of groups that were coded as running times. The means and standard deviations are shown at the bottom for the four prior days. Both the digit span and the number of mnemonic codes show substantial drops on the experimental day. The last three columns are the number of times, non-times, and total digits recalled in the after-session report, and again, there are substantial drops on the experimental day.



EXPERIMENT I - NON-TIME SEQUENCES

	DIGIT SPAN	% TIMES IN RETROSPECTIVE REPORTS	AFTER-SESSION REPORT: NUMBER OF TIMES	AFTER-SESSION REPORT: NUMBER OF NON-TIMES	AFTER-SESSION REPORT: NUMBER OF DIGITS
MONDAY	13.1	65	26	7	110
TUESDAY	18.8	62	24	5	98
WEDNESDAY	16.2	70	31	4	123
THURSDAY	15.6	75	43	3	165
Mean	15.9	68	31	4.75	124
S.D.	2.34	5.72	8.52	1.71	29.2
FRIDAY	12.7	41 (18 REGULAR, 23 CONVERTED)	12	10	79

This first experiment shows that when SF can't use his running time mnemonic, there is a substantial drop in his digit span performance. By a clever change of his control strategies, he was able to overcome the difficulties somewhat and bring his mnemonic system to bear.

The next slide shows a summary of several experiments. On the top is our first experiment, and just below it is our second experiment, which is almost the converse of the first one. We reasoned that if the running time mnemonic is important, then SF's performance should improve if we give him all running times. Since we know how SF will normally group the digits, we arranged the sequences so that SF's groups all corresponded to running times. The result was that SF's performance jumped by 22% (from 16 to 19.5).

The next experiment was an attempt to see if SF could code sequences at a fast rate, so we compared the normal rate (1 digit/sec.) with a fast rate (3 digits/sec.) and this almost completely wiped out his performance.

The next several experiments are a variety of rehearsal suppression experiments to see what part of SF's performance is based on STM. In the first experiment, SF recited the alphabet as quickly as he could immediately after the list was presented, followed by recall 20 sec. later. The drop in performance corresponds almost exclusively to loss of the rehearsal group at the end. Again, about half way through the session, SF changed his grouping strategy to produce a smaller rehearsal group at the end, and this strategy did reduce the interference considerably.

The next two experiments were visual suppression experiments in which SF either copied geometric slopes or performed a more difficult rotate-and-copy task for 20 sec. between the list and recall. We had thought that

EXPERIMENTS

UNCODABLE SEQUENCES	15.9	→	12.9
GOOD SEQUENCES	16.0	→	19.5
FAST PRESENTATION	19.5	→	9.1
REHEARSAL SUPPRESSION			
RECITE ALPHABET	20.6	→	16.3
VISUAL SUPPRESSION-COPY	25.7	→	26.5
VISUAL SUPPRESSION-ROTATE	25.7	→	24.5
HYA - HYA	25.7	→	23.9
SHADOWING	31.6	→	20.5
ALPHABET	25.7	→	6.9
FREE RECALL	30.4	→	30.9
GROUPING BY 3's	30.2	→	27.5
GROUPING BY 4's	30.2	→	29.3

there might be some visual-spatial coding, but this visual suppression had no effect at all.

The next two experiments were an attempt to occupy STM during presentation of the digits to see how important the rehearsal buffer is for coding. To our great surprise, SF was able to say "Hya-Hya" between presentation of the digits without any trouble at all. He said that he could organize this verbal sequence independently and somehow hear it in a different location than where he was listening to the digits and coding them. In the last experiment in this series, SF had to shadow letters of the alphabet interspersed with the digits, and this procedure did cause considerable interference. Accessing memory seems to be much more demanding than maintaining a known verbal utterance in the rehearsal buffer.

In the next experiment, we wanted to know if any of SF's skill would transfer to new materials. Did SF learn anything general in the way of memory control structures that would transfer to some new domain? The answer is no. SF's memory span for consonants was less than seven.

The next experiment was a free-recall experiment. SF's performance didn't improve, but his recall was very systematic. In every case, he recalled the groups in backward order. Starting with the rehearsal group, he worked his way backward through the list, ending with the first group. Recall within a group was, of course, forward.

The next two experiments addressed the question of how important is the group size for maintaining the super groups. Does SF need to have groups of 4 followed by groups of 3, or vice versa? We instructed SF to group all by 4's or all by 3's. Outside of a lot of complaining, there was not much decrement in performance. The difference between these two conditions simply reflects the fact that the total number of groups, rather than the total number of digits, remained invariant.

16

We have conducted a lot of other interesting experiments, but we will report one final one today. The question is how good is SF compared to other known memory experts. The only objective comparison we could find in the literature is between Luria's S (Luria, 1968) and Hunt & Love's VP (Hunt & love, 1972). Both of these people have been compared on the 50-digit matrix shown in the next slide. The task is to study this matrix until it is committed to memory, and then answer some questions about it. For example, recall the third column, the first column up, the zig-zag diagonals, etc. The next slide compares performance of these three people on this matrix. The performance is very comparable for all three experts. It is interesting to note that Luria's S claimed to be scanning a visual image, whereas Hunt & Love's VP was using verbal associations. We know what SF did. He simply coded each row as a running time, and his recall performance was a straightforward retrieval of this information, group by group. Yet SF's performance is comparable to Luria's S, who claimed to be scanning a visual image. In other respects, SF's control strategies in the digit span task are remarkably similar to those reported by VP (Hunt & Love, 1972). In general, then, SF's expertise for digits is at least as good as that of the best mnemonists reported in the literature.

Conclusions

We have produced, in a very short amount of time, and with a person with no special memory abilities, a memory expert with a remarkable skill within a restricted domain. The 150 hours or so that SF has spent is miniscule compared to the thousands of hours of practice required to become a chess master (Chase & Simon, 1973) or a general mnemonist (Hunt & Love, 1972; Luria, 1968). We think we understand how SF has done it:

6	6	8	0
5	4	3	2
1	6	8	4
7	9	3	5
4	2	3	7
3	8	9	1
1	0	0	2
3	4	5	1
2	7	6	8
1	9	2	6
2	9	6	7
5	5	2	0
x	0	1	x

STUDY AND RECALL TIME (SEC.)
THREE MNEMONISTS ON LURIA'S 50-DIGIT MATRIX

	Luria's S	Hunt & Love's VP	SF
STUDY TIME	180	390	187
RECALL TIME			
ENTIRE MATRIX	40	42	43
THIRD COLUMN	80	58	41
SECOND COLUMN	25	39	41
SECOND COLUMN UP	30	40	47
ZIG ZAG	35		64

(a) There is no evidence of an increase in STM capacity. There are many indications of this. (1) His rehearsal group never exceeds 6 digits. (2) His group size never exceeds 5 digits. (3) He was unable to construct super groups with more than 4 or 5 groups. (4) His memory span for consonants is less than seven.

(b) SF has acquired a large repertoire of meaningful associations in LTM between digits and running times. This is comparable to the large repertoire of chess patterns in LTM that, according to Chase and Simon, (1973), underlies the memory feats of chess masters for chess positions.

(c) SF has acquired a control structure in LTM, based on grouping and rehearsing, that preserves temporal order and aids in recall.

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Footnote

[1]To give some indication of SF's skill, he is a member of the university track and cross-country team, he was a member of a junior-college national championship marathon team, and a member of the Human Energy Running Club. SF trains 10-13 miles a day. SF is now 20 years old, and he has been competing in numerous long-distance events in the Eastern region of the U.S. for the past 7 years. SF's best events are the 3-mile, 5-mile and marathon, and his best times in these events are 14:39, 25:40, and 2:39:36, respectively. SF rates himself at the 98th percentile of runners for events over 10 miles. In other respects, SF seems to have average memory abilities and average intelligence test scores (SAT=990, GRE=1140), although he has a high grade-point average (3.80).

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